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IN THE HIGH SPEED
WATER TUNNEL

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GRADUATE AERONAUTICAL LABORATORIES
CALIFORNIA INSTITUTE OF TECHNOLOGY

High Speed Water Tunnel

GALCIT Report No. HSWT-1137

NSRDC FAIRED TOWLINE TESTS
in the
HIGH SPEED WATER TUNNEL

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Pasadena, California
October 1979

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ABSTRACT

Lift, drag and pitching moment data for aluminum and rubber models of a segment of the NSRDC towline are presented. Deflections on the rubber model were also measured through a pitch angle range of $+1^{\circ}$ through -4° with water velocities ranging up to 68 feet per second.

INDEX OF RUNS

| Run No. | Model | Vel., ft/sec | Pitch, deg. | σ | Remarks |
|---------|----------|--------------|-------------|----------|------------------------------------|
| 1 | Aluminum | 40 | Vary | Vary | |
| 2 | | — | — | — | N.G. |
| 3 | | 68 | Vary | 1.25 | |
| 4 | | Vary | -0.18 | Vary | |
| 5 | Rubber | " | Vary | " | |
| 6 | | 40 | " | 3.18 | Fabric covering loosened from body |
| 7 | | " | " | " | Fabric repaired |
| 8 | | 50 | " | 2.34 | |
| 9 | | " | — | " | Repeat of 1 data point from Run 8 |
| 10 | | — | — | — | Balance Tare Run |
| 11 | | Vary | +1.00 | Vary | |
| 12 | | " | 0.00 | " | |
| 13 | | " | -1.00 | " | |
| 14 | | " | -2.00 | " | |
| 15 | | " | -3.00 | " | |
| 16 | | " | -4.00 | " | |
| 17 | | 50 | -0.60 | 2.33 | |
| 18 | | Vary | -4.00 | Vary | |
| 19 | | " | +1.00 | " | Model 10% truncated |

INDEX OF FIGURES

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TABLE I

Nomenclature

Designation

| | |
|--------------|---|
| A | = Planform area of foil, $B \times C$ |
| B | = Span of foil |
| C, (LC) | = Chord of foil |
| C_D , (CD) | = Drag coefficient, $D/q_0 A$ |
| C_L , (CL) | = Lift coefficient, $L/q_0 A$ |
| C_M , (CM) | = Pitching moment coefficient, $M/q_0 C A$ |
| D, (DRAG) | = Drag force, positive when acting in the direction of flow parallel to the longitudinal centerline of the working section. |
| L, (LIFT) | = Lift force, positive when acting upward and normal to the direction of flow which is parallel to the longitudinal centerline of the working section. |
| M, (MOMENT) | = Pitching moment, positive when tending to rotate the foil leading edge upward about an axis taken normal to the longitudinal centerline of the working section through the 25% chord point. |
| Nose | = Leading edge |
| P_0 , (PO) | = Static pressure of water in working section, absolute |
| P_v , (PV) | = Vapor pressure of water at test temperature |
| q_0 , (QO) | = Dynamic pressure of water in working section, $\frac{1}{2} \rho V_0^2$ |
| R_n , (RN) | = Reynolds number, $V_0 C / \nu$ |
| T. E. | = Trailing edge |
| V_0 , (VO) | = Water velocity in working section |
| W_m , (WM) | = Weight of mercury |
| W_w , (WW) | = Weight of water |

TABLE I (Cont'd.)

| | |
|--------------------|--|
| α , (PITCH) | = Pitch angle; angle of attack of foil measured between working section longitudinal centerline and foil chordline, positive when leading edge is rotated upward |
| ρ , (RHO) | = Density of water |
| ν , (NU) | = Kinematic viscosity of water |
| σ , (SIGMA) | = Index of cavitation based on vapor pressure of water, $(P_0 - P_v)/q_0$ |
| CCN | = Card code number used to identify the nature of the data point as follows: CCN 110 = Pretest reference readings 120 = Model test data 130 = Post test reference readings |
| PSF | = Pounds per square foot |
| PSFA | = Pounds per square foot absolute |
| Aluminum | = Rigid aluminum model |
| Rubber | = Flexible silicone rubber model |

Note: Equivalent nomenclature designation, used in computer printout Table II, appears in parenthesis.

TABLE II
RUN DATA AND THREE COMPONENT
COEFFICIENTS CORRECTED FOR BALANCE INTERACTIONS

GALCIT Report
HSWT-1137

THREE COMPONENT
RUN DATA CORRECTED FOR BALANCE INTERACTIONS

CONSTANTS: TEMP = 73.70000 DEG F
PV = 59.25453 PSF
WH = 62.23323 LBS/CUFT
LC = 0.20000 FT

RHO = 1.93529 SLUG/CUFT
NU = 0.10022E-04 SEC
WH = 845.25391 LBS/CUFT
A = 0.10000 SLUG

| RUN CCN CARD | | VELOCITY | PRESSURE | PITCH | Q0 | RN | SIGMA | LIFT | DRAG | MOMENT | CL | CD | CM | L/D |
|--------------|-----|-----------|----------|--------|-------|--------|-------|-------|---------|--------|--------|---------|--------|---------|
| | | VO,FT/SEC | PO,PSFA | DEG | PSF | 10 E-6 | L,LBS | D,LBS | M,FT-LB | | | | | |
| 1 | 110 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.31 | 0.0113 | 0.0173 | 0.0014 | 0.65 |
| 1 | 120 | 1 | 39.89 | 2022.9 | 0.0 | 1539.6 | 0.796 | 1.30 | 1.7 | 0.04 | 0.0113 | 0.0166 | 0.0014 | -3.85 |
| 1 | 120 | 2 | 39.94 | 2059.9 | -1.00 | 1533.5 | 0.797 | 1.30 | -10.9 | -2.8 | -0.35 | -0.3708 | 0.0177 | - |
| 1 | 120 | 3 | 39.96 | 2059.9 | 1.00 | 1537.3 | 0.795 | 1.30 | 15.1 | -2.7 | 0.09 | 0.0980 | 0.0177 | 5.95 |
| 1 | 120 | 4 | 39.97 | 2059.9 | -2.00 | 1530.3 | 0.794 | 1.31 | -23.8 | 2.9 | -0.13 | -0.1557 | 0.0190 | -0.0043 |
| 1 | 120 | 5 | 39.99 | 2059.9 | -3.00 | 1530.4 | 0.796 | 1.30 | -40.1 | 3.0 | -0.27 | -0.2602 | 0.0198 | -0.0088 |
| 1 | 120 | 6 | 39.83 | 2059.9 | -4.00 | 1534.9 | 0.795 | 1.31 | -52.4 | 3.2 | -0.17 | -0.3412 | 0.0210 | -0.0122 |
| 1 | 110 | 93 | 0 | 3614.3 | -3.00 | 1539.6 | 0.796 | 2.4 | -0.2 | 0.02 | -0.34 | -0.3502 | 0.0115 | -0.0126 |
| 1 | 120 | 7 | 39.89 | 3614.3 | -4.00 | 1539.6 | 0.796 | 2.31 | -53.9 | 3.3 | -0.31 | -0.2745 | 0.0213 | -0.0099 |
| 1 | 120 | 8 | 39.90 | 3614.3 | -3.00 | 1540.4 | 0.795 | 2.31 | -42.3 | 3.3 | -0.31 | -0.2745 | 0.0213 | -12.89 |
| 1 | 120 | 9 | 39.92 | 3614.3 | -2.00 | 1541.9 | 0.797 | 2.31 | -30.4 | 3.1 | -0.18 | -0.1970 | 0.0204 | -0.0057 |
| 1 | 120 | 10 | 39.87 | 3614.3 | -1.00 | 1538.0 | 0.796 | 2.31 | -16.2 | 3.0 | -0.06 | -0.1050 | 0.0197 | -0.0028 |
| 1 | 120 | 11 | 39.89 | 3614.3 | 0.0 | 1539.6 | 0.796 | 2.31 | -2.3 | 3.0 | 0.02 | -0.0144 | 0.0194 | 0.0006 |
| 1 | 120 | 12 | 39.93 | 3614.3 | 1.00 | 1542.7 | 0.797 | 2.31 | 11.5 | 3.0 | 0.12 | 0.3745 | 0.0192 | 0.0038 |

CONSTANTS: TEMP = 73.39993 DEG F
PV = 58.66269 PSF
WH = 62.20303 LBS/CUFT
LC = 0.20000 FT

RHO = 1.93538 SLUG/CUFT
NU = 0.10015E-04 SEC
WH = 845.27783 LBS/CUFT
A = 0.10000 SLUG

| RUN CCN CARD | | VELOCITY | PRESSURE | PITCH | Q0 | RN | SIGMA | LIFT | DRAG | MOMENT | CL | CD | CM | L/D |
|--------------|-----|-----------|----------|--------|-------|--------|-------|-------|---------|--------|-------|---------|--------|--------|
| | | VO,FT/SEC | PO,PSFA | DEG | PSF | 10 E-6 | L,LBS | D,LBS | M,FT-LB | | | | | |
| 3 | 110 | 95 | 0.0 | 5670.1 | -3.00 | 4617.8 | 1.343 | 1.27 | 3.1 | -0.5 | 0.06 | 0.0102 | 0.0155 | 0.0001 |
| 3 | 120 | 18 | 67.57 | 5670.1 | 0.0 | 4472.2 | 1.351 | 1.25 | 4.5 | -6.9 | 0.01 | 0.0102 | 0.0155 | 0.0001 |
| 3 | 120 | 19 | 68.16 | 5670.1 | 1.00 | 4495.5 | 1.355 | 1.25 | 4.2 | 6.6 | 0.33 | 0.0948 | 0.0158 | 0.0037 |
| 3 | 120 | 20 | 68.13 | 5670.1 | -1.00 | 4487.7 | 1.354 | 1.25 | -34.7 | 7.1 | -0.31 | -0.0773 | 0.0159 | -4.87 |
| 3 | 120 | 21 | 68.19 | 5670.1 | -2.00 | 4481.7 | 1.354 | 1.25 | -74.9 | 7.3 | -0.61 | -0.1668 | 0.0163 | -10.24 |
| 3 | 120 | 22 | 67.98 | 5670.1 | -3.00 | 4472.2 | 1.351 | 1.25 | -113.7 | 7.7 | -0.92 | -0.2543 | 0.0172 | -14.79 |
| 3 | 120 | 23 | 67.92 | 5670.1 | -4.00 | 4466.4 | 1.350 | 1.26 | -151.9 | 8.1 | -1.20 | -0.3401 | 0.0182 | -18.65 |
| 3 | 120 | 24 | 67.93 | 5670.1 | -3.00 | 4472.2 | 1.351 | 1.25 | -114.5 | 7.8 | -0.07 | -0.2561 | 0.0174 | -14.75 |
| 3 | 120 | 25 | 68.10 | 5670.1 | -2.00 | 4487.7 | 1.354 | 1.25 | -75.9 | 7.3 | -0.25 | -0.1692 | 0.0163 | -10.35 |
| 3 | 120 | 26 | 67.98 | 5670.1 | -1.00 | 4472.2 | 1.351 | 1.25 | -36.5 | 7.2 | -0.25 | -0.0817 | 0.0161 | -5.07 |
| 3 | 120 | 27 | 67.99 | 5670.1 | 1.00 | 4472.2 | 1.351 | 1.25 | 42.3 | 7.0 | 0.29 | 0.0947 | 0.0156 | 0.0032 |
| 3 | 120 | 29 | 67.99 | 5670.1 | -0.18 | 4472.2 | 1.351 | 1.25 | -2.8 | 6.8 | -0.34 | -0.0062 | 0.0152 | -0.41 |
| 4 | 110 | 95 | 0.0 | 5670.1 | -3.00 | 4472.2 | 1.351 | 1.25 | -114.5 | 7.8 | -0.07 | -0.2561 | 0.0174 | -14.75 |

THREE COMPONENT
RUN DATA CORRECTED FOR BALANCE INTERACTIONS

GALCIT Report
HSWT-1137

CONSTANTS: TEMP = 73.39999 DEG F
PV = 58.66269 PSF
WW = 62.20303 LB/CUFT
LC = 0.29000 FT

RHO = 1.93538 SLUG/CUFT
NU = 0.10061E-34 SOFT/SEC
WW = 845.27734 LB/CUFT
A = 0.10000 SQFT

RUN CCN CARD VELOCITY PRESSURE PITCH Q0 ROLL 10 E-6 ROLL 10 E-6 LIFT DRAG MOMENT CL CO CM L/0
VO,FT/SEC PO,PSFA DEG PSF LB D,LBS D,LBS M,FT-LB

4 120 29 65.09 5670.1 -0.18 4099.5 1.294 1.37 -2.5 6.4 -0.07 -0.0061 0.0155 -0.0009 -0.39
4 120 33 60.35 5670.1 -0.18 3524.9 1.203 1.59 -2.5 5.6 -0.37 -0.0072 0.0160 -0.0010 -0.45
4 120 31 55.00 5670.1 -0.18 2927.1 1.093 1.92 -3.6 4.8 -0.06 -0.0124 0.0163 -0.0010 -0.76
4 120 -- 32 50.11 5670.1 -0.18 2430.2 0.996 2.31 -3.2 4.1 -0.06 -0.0130 0.0167 -0.0012 -0.78
4 120 33 44.97 5670.1 -0.18 1956.6 0.894 2.87 -3.2 3.4 -0.35 -0.0161 0.0172 -0.0013 -0.94
4 120 34 39.96 5670.1 -0.18 1545.1 0.795 3.63 -3.5 2.8 -0.05 -0.0229 0.0179 -0.0016 -1.27
4 120 35 34.92 5670.1 -0.18 1180.2 0.694 4.75 -3.0 2.1 -0.05 -0.0255 0.0178 -0.0023 -1.43
4 120 36 29.98 5670.1 -0.18 869.6 0.596 6.45 -2.9 1.6 -0.06 -0.0336 0.0197 -0.0034 -1.79
4 120 37 25.02 5670.1 -0.18 605.6 0.497 9.27 -3.0 1.2 -0.07 -0.0498 0.0193 -0.0059 -2.58
4 120 39 19.91 5670.1 -0.18 383.6 0.356 14.63 -2.8 -0.9 -0.06 -0.0737 0.0230 -0.0084 -3.20
4 120 39 67.3 5670.1 -0.18 4472.2 1.351 1.25 -2.8 7.0 -0.06 -0.063 0.0158 -0.0007 -0.40
4 120 40 65.03 5670.1 -0.18 4091.7 1.293 1.37 -2.9 6.5 -0.07 -0.0070 0.0158 -0.0008 -0.45

CONSTANTS: TEMP = 73.89999 DEG F
PV = 59.64903 PSF
WW = 62.19826 LB/CUFT
LC = 0.20000 FT

RHO = 1.93523 SLUG/CUFT
NU = 0.99967E-05 SOFT/SEC
WW = 845.23779 LB/CUFT
A = 0.10000 SQFT

RUN CCN CARD VELOCITY PRESSURE PITCH Q0 ROLL 10 E-6 ROLL 10 E-6 LIFT DRAG MOMENT CL CO CM L/0
VO,FT/SEC PO,PSFA DEG PSF LB D,LBS D,LBS M,FT-LB

5 110 42 0.0 2066.6 0.0 385.9 0.400 5.20 0.0 0.0 0.01 0.0171 0.0252 0.0007 0.68
5 120 43 19.97 2066.6 0.0 864.9 0.593 2.32 1.9 2.4 0.04 0.0223 0.0276 0.0022 0.81
5 120 44 29.00 2066.6 0.0 1177.0 0.698 1.71 2.3 3.1 0.01 0.0196 0.0266 0.0004 0.74
5 120 45 34.88 2066.6 0.0 500 385.1 0.399 5.21 1.8 1.1 0.03 0.065 0.0282 0.0034 1.65
5 120 46 19.95 2066.6 1.00 383.5 0.398 5.23 1.1 1.1 0.03 0.0714 0.0278 0.0044 2.78
5 120 47 19.91 2066.6 -0.50 383.5 0.393 5.23 0.1 1.1 0.03 0.0225 0.0284 0.0015 0.09
5 120 48 19.91 2066.6 -1.00 382.8 0.358 5.24 -1.1 1.1 0.00 -0.0295 0.0265 0.0005 -1.04
5 120 49 19.91 2066.6 -1.50 385.1 0.399 5.21 -2.2 1.1 0.00 -0.0563 0.0293 -0.0005 -1.92
5 120 50 19.95 2066.6 -2.00 384.3 0.399 5.22 -2.2 1.1 -0.01 -0.0858 0.0289 -0.0015 -2.97
5 120 51 19.93 2066.6 -3.00 382.8 0.398 5.24 -5.7 1.1 -0.01 -0.1501 0.0291 -0.0052 -5.16
5 120 52 19.89 2066.6 -4.00 365.1 0.399 5.21 -8.3 1.2 -0.04 -0.2165 0.0305 -0.0054 -7.10
5 120 53 19.95 2066.6 0.0 335.5 0.398 5.23 0.9 1.1 0.01 0.0209 0.0278 0.0007 0.75
5 120 54 19.91 2066.6 0.0 801.0 0.597 2.33 1.9 2.3 0.02 0.0224 0.0272 0.0010 0.82
5 120 55 29.83 2066.6 -0.50 862.6 0.597 2.33 0.4 2.4 0.02 0.0449 0.0279 0.0013 0.18
5 120 56 29.86 2066.6 -1.00 364.9 0.398 5.22 -2.4 1.1 0.00 -0.0180 0.0274 0.0001 -0.66

THREE COMPONENT
RUN DATA CORRECTED FOR BALANCE INTERACTIONS

GALCIT Report
HSWT-1137

CONSTANTS: TEMP= 73.89999 DEG F
PV= 59.64909 PSF
Wt= 62.19826 LBS/CUFT
LC= 0.20000 FT

RHO= 1.93523 SLUG/CUFT
NU= 0.9967E-05
Wt= 845.23779 SQFT/SEC
LC= 0.10000 LBS/ CUFT
A= 0.10000 SQFT

| RUN CCN CARD | | VELOCITY | PRESSURE | PITCH | Q0 | RN | SIGMA | LIFT | DRAG | MOMENT | CL | CD | CM | L/D | |
|--------------|-----|------------|----------|--------|-------|--------|-------|-------|---------|--------|-------|---------|--------|---------|-------|
| | | VJ, FT/SEC | P0, PSFA | DEG | PSF | 10 E-6 | L,LBS | D,LBS | M,FT-LB | | | | | | |
| 5 | 120 | 58 | 29.87 | 2065.6 | -2.00 | 863.3 | 0.598 | 2.32 | -5.0 | 2.4 | -0.03 | -0.0584 | 0.0277 | -0.0016 | -2.11 |
| 5 | 120 | 59 | 29.92 | 2066.6 | -3.00 | 866.4 | 0.599 | 2.32 | -6.7 | 2.4 | -0.06 | -0.0100 | 0.0277 | -0.0033 | -3.62 |
| 5 | 120 | 60 | 29.92 | 2056.6 | -4.00 | 866.4 | 0.599 | 2.32 | -12.0 | 2.4 | -0.07 | -0.1386 | 0.0281 | -0.0039 | -4.92 |
| 5 | 120 | 61 | 29.91 | 2066.6 | 0.50 | 865.7 | 0.599 | 2.32 | 3.9 | 2.3 | -0.03 | 0.0452 | 0.0266 | 0.0019 | 1.70 |
| 5 | 120 | 62 | 29.94 | 2066.6 | 1.00 | 867.2 | 0.599 | 2.31 | 5.7 | 2.4 | -0.05 | 0.0657 | 0.0274 | 0.0027 | 2.39 |
| 5 | 120 | 63 | 29.96 | 2066.6 | 0.0 | 868.8 | 0.599 | 2.31 | 2.3 | 2.4 | -0.02 | 0.0323 | 0.0272 | 0.0014 | 0.86 |
| 5 | 130 | 64 | 0.0 | 2066.6 | 0.0 | 868.8 | 0.599 | 2.31 | 0.0 | 0.1 | 0.01 | 0.01 | | | |

CONSTANTS: TEMP= 73.70000 DEG F
PV= 59.25453 PSF
Wt= 62.20323 LBS/ CUFT
LC= 0.20001 FT

RHO= 1.93529 SLUG/ CUFT
NU= 0.10022E-04
Wt= 845.25391 SQFT/SEC
LC= 0.10000 LBS/ CUFT
A= 0.10000 SQFT

| RUN CCN CARD | | VELOCITY | PRESSURE | PITCH | Q0 | RN | SIGMA | LIFT | DRAG | MOMENT | CL | CD | CM | L/D | |
|--------------|-----|------------|----------|--------|-------|--------|-------|-------|---------|--------|-------|---------|--------|---------|-------|
| | | VJ, FT/SEC | P0, PSFA | DEG | PSF | 10 E-6 | L,LBS | D,LBS | M,FT-LB | | | | | | |
| 6 | 110 | 94 | 0.0 | 4945.6 | -3.00 | 1530.0 | 0.796 | 3.18 | 2.9 | -0.4 | -0.11 | 0.0066 | 0.0222 | -0.0037 | 0.03 |
| 6 | 120 | 67 | 39.87 | 4945.6 | 0.0 | 1541.1 | 0.796 | 3.17 | 2.3 | -3.4 | -0.39 | 0.0167 | 0.0222 | -0.0028 | 0.66 |
| 6 | 120 | 68 | 39.91 | 4945.6 | 0.50 | 1541.1 | 0.796 | 3.17 | 2.3 | -3.4 | -0.39 | 0.0167 | 0.0222 | -0.0028 | 0.66 |
| 6 | 120 | 69 | 39.93 | 4945.6 | 1.00 | 1522.7 | 0.797 | 3.17 | 4.7 | 3.4 | -0.05 | 0.0305 | 0.0217 | -0.0016 | 1.40 |
| 6 | 120 | 70 | 39.96 | 4945.6 | -0.50 | 1537.3 | 0.795 | 3.18 | -1.8 | 3.5 | -0.12 | -0.0119 | 0.0226 | -0.0040 | -0.53 |
| 6 | 120 | 71 | 39.89 | 4945.6 | -1.00 | 1539.6 | 0.796 | 3.17 | -6.7 | 3.5 | -0.17 | -0.0303 | 0.0229 | -0.0056 | -1.32 |
| 7 | 110 | 94 | 0.0 | 4945.6 | -3.00 | 1535.7 | 0.795 | 3.18 | 2.9 | -0.4 | -0.06 | 0.016 | 0.0221 | -0.0031 | -0.36 |
| 7 | 120 | 74 | 39.84 | 4945.6 | -1.00 | 1535.7 | 0.795 | 3.18 | -6.6 | 3.4 | -0.13 | -0.0301 | 0.0221 | -0.0043 | -1.36 |
| 7 | 120 | 75 | 39.87 | 4945.6 | -2.00 | 1538.0 | 0.796 | 3.18 | -8.9 | 3.3 | -0.17 | -0.0576 | 0.0217 | -0.0057 | -2.65 |
| 7 | 120 | 76 | 39.84 | 4945.6 | -3.00 | 1535.7 | 0.795 | 3.19 | -13.1 | 3.4 | -0.22 | -0.0856 | 0.0221 | -0.0071 | -3.87 |
| 7 | 120 | 77 | 39.88 | 4945.6 | -4.00 | 1538.8 | 0.796 | 3.18 | -17.0 | 3.5 | -0.25 | -0.1102 | 0.0226 | -0.0080 | -4.87 |
| 7 | 120 | 78 | 39.88 | 4945.6 | 1.00 | 1536.8 | 0.796 | 3.18 | 4.2 | 3.3 | -0.05 | 0.0272 | 0.0216 | -0.0016 | 1.26 |
| 7 | 120 | 79 | 39.89 | 4945.6 | 0.0 | 1539.6 | 0.796 | 3.17 | -0.3 | 3.3 | -0.10 | -0.0021 | 0.0212 | -0.0033 | -0.10 |
| 8 | 110 | 95 | 0.0 | 5670.0 | -3.00 | 2397.5 | 0.993 | 2.34 | 3.1 | -0.5 | -0.16 | -0.0055 | 0.0201 | -0.0034 | -0.27 |
| 8 | 120 | 82 | 49.78 | 5064.9 | 0.0 | 2395.2 | 0.993 | 2.34 | -1.3 | 4.8 | -0.12 | 0.0063 | 0.0207 | -0.0024 | 0.30 |
| 8 | 120 | 83 | 49.75 | 5664.9 | 0.50 | 2395.2 | 0.993 | 2.34 | 1.5 | 5.0 | -0.12 | 0.0063 | 0.0207 | -0.0024 | 0.30 |
| 8 | 120 | 84 | 49.74 | 5664.9 | 1.00 | 2394.4 | 0.993 | 2.34 | 4.1 | 4.9 | -0.07 | 0.0173 | 0.0206 | -0.0015 | 0.84 |
| 8 | 120 | 85 | 49.74 | 5664.9 | -0.50 | 2394.4 | 0.993 | 2.34 | -3.8 | 4.9 | -0.18 | -0.0157 | 0.0206 | -0.0038 | -0.76 |
| 8 | 120 | 86 | 49.77 | 5664.9 | -1.00 | 2396.7 | 0.993 | 2.34 | -6.4 | 4.9 | -0.22 | -0.0267 | 0.0206 | -0.0045 | -1.30 |
| 8 | 120 | 87 | 49.76 | 5664.9 | -2.00 | 2396.7 | 0.993 | 2.34 | -11.4 | 5.0 | -0.30 | -0.0478 | 0.0207 | -0.0063 | -2.31 |
| 8 | 120 | 88 | 49.76 | 5664.9 | -3.00 | 2396.0 | 0.993 | 2.34 | -16.0 | 5.0 | -0.36 | -0.0666 | 0.0208 | -0.0075 | -3.20 |

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THREE COMPONENT
RUN DATA CORRECTED FOR BALANCE INTERACTIONS

GALCIT Report
HSWT-1137

CONSTANTS: TEMP = 75.00000 DEG F
PV = 59.84639 PSF
HW = 62.19731 LBS/CUFT
LC = 0.20000 FT

| RUN | CCN CARD | VELOCITY V, FT/SEC | PRESSURE P, PSF | PITCH DEG | Q0 | | RN | | SIGMA | | LIFT L,LBS | | DRAG D,LBS | | MOMENT M, FT-LB | | CL | | CD | | CN | | L/D | |
|-----|----------|-----------------------|--------------------|--------------|-------|--------|-------|--------|-------|------|---------------|-------|---------------|---------|--------------------|---------|-------|----|----|----|----|----|-----|--|
| | | | | | PSF | 10 E-6 | PSF | 10 E-6 | L | R | U | V | W | CL | CD | CL | CD | CL | CD | CL | CD | CL | CD | |
| 9 | 110 | 95 | 0.0 | 5669.8 | -3.00 | 2394.3 | 0.996 | 2.34 | -12.0 | 3.1 | -0.5 | 0.06 | -0.17 | -0.0502 | 0.0220 | -0.0036 | -2.28 | | | | | | | |
| 9 | 120 | 91 | 49.74 | 5664.7 | -3.03 | | | | | 3.1 | -0.5 | 0.06 | | | | | | | | | | | | |
| 11 | 110 | 95 | 0.0 | 5669.8 | -3.03 | | | | | 3.1 | -0.3 | | | | | | | | | | | | | |
| 11 | 120 | 99 | 10.29 | 5664.7 | 1.00 | 102.5 | 0.206 | 54.69 | | 1.3 | 0.9 | -0.02 | 0.0761 | 0.0233 | -0.0026 | -4.18 | | | | | | | | |
| 11 | 120 | 100 | 19.91 | 5664.7 | 1.00 | 383.5 | 0.399 | 14.61 | | 2.9 | 1.9 | -0.01 | 0.0460 | 0.0221 | -0.0004 | 3.27 | | | | | | | | |
| 11 | 120 | 101 | 29.87 | 5664.7 | 1.00 | 863.3 | 0.993 | 6.49 | | 4.1 | 3.3 | 0.03 | 0.0359 | 0.0215 | 0.0010 | 2.18 | | | | | | | | |
| 11 | 120 | 102 | 39.84 | 5664.7 | 1.00 | 1535.7 | 0.798 | 3.65 | | 5.5 | 3.3 | 0.03 | | | | | | | | | | | | |
| 11 | 120 | 103 | 49.74 | 5664.7 | 1.00 | 2393.6 | 0.996 | 2.34 | | 6.7 | 5.2 | 0.12 | 0.0362 | 0.0216 | 0.0026 | 1.68 | | | | | | | | |
| 11 | 120 | 104 | 59.81 | 5664.7 | 1.00 | 3461.1 | 1.198 | 1.62 | | 11.3 | 7.6 | 0.18 | 0.0328 | 0.0219 | 0.0025 | 1.50 | | | | | | | | |
| 11 | 120 | 105 | 49.75 | 5664.7 | 1.00 | 2395.1 | 0.597 | 2.34 | | 8.7 | 5.2 | 0.12 | 0.0364 | 0.0217 | 0.0025 | 1.67 | | | | | | | | |
| 11 | 120 | 106 | 39.80 | 5664.7 | 1.00 | 1532.6 | 0.797 | 3.65 | | 5.7 | 3.4 | 0.06 | 0.0375 | 0.0225 | 0.0019 | 1.67 | | | | | | | | |
| 11 | 120 | 107 | 29.83 | 5664.7 | 1.00 | 859.4 | 0.597 | 6.52 | | 3.9 | 2.1 | 0.01 | 0.0455 | 0.0239 | 0.0003 | 1.90 | | | | | | | | |
| 11 | 120 | 108 | 19.95 | 5664.7 | 1.00 | 385.1 | 0.400 | 14.56 | | 2.6 | 1.1 | -0.01 | 0.0673 | 0.0277 | -0.0018 | 2.43 | | | | | | | | |
| 11 | 120 | 109 | 10.29 | 5634.7 | 1.00 | 102.5 | 0.206 | 54.69 | | 1.3 | 0.4 | -0.01 | 0.0965 | 0.0427 | -0.0033 | 2.26 | | | | | | | | |
| 11 | 130 | 110 | 0.0 | 5664.7 | 1.00 | | | | | 3.1 | -0.3 | | | | | | | | | | | | | |
| 12 | 110 | 112 | 0.0 | 5664.7 | 0.0 | | | | | 3.1 | -0.5 | | | | | | | | | | | | | |
| 12 | 120 | 113 | 9.93 | 5654.7 | 0.3 | 95.5 | 0.199 | 58.69 | | 0.4 | 0.2 | -0.01 | 0.0444 | 0.0259 | -0.0036 | 1.71 | | | | | | | | |
| 12 | 120 | 114 | 19.99 | 5654.7 | 0.3 | 386.6 | 0.403 | 14.53 | | 5.5 | 0.9 | -0.32 | 0.0134 | 0.0232 | -0.0028 | 0.58 | | | | | | | | |
| 12 | 120 | 115 | 29.94 | 5654.7 | 0.3 | 867.2 | 0.600 | 6.45 | | 0.5 | 1.9 | -0.02 | 0.0054 | 0.0220 | -0.0010 | 0.25 | | | | | | | | |
| 12 | 120 | 116 | 39.85 | 5654.7 | 0.3 | 1536.4 | 0.798 | 3.65 | | 1.3 | 3.3 | 0.01 | 0.0086 | 0.0212 | -0.0005 | 0.40 | | | | | | | | |
| 12 | 120 | 117 | 49.78 | 5654.7 | 0.3 | 2397.4 | 0.597 | 2.34 | | 3.6 | 5.0 | 0.07 | 0.0149 | 0.0209 | 0.0015 | 0.71 | | | | | | | | |
| 12 | 120 | 119 | 59.79 | 5654.7 | 0.3 | 3459.5 | 1.198 | 1.62 | | 5.1 | 7.4 | 0.06 | -0.0147 | 0.0214 | -0.0009 | 0.69 | | | | | | | | |
| 12 | 120 | 119 | 49.80 | 5654.7 | 0.3 | 2396.8 | 0.598 | 2.34 | | 3.6 | 5.2 | 0.07 | 0.0149 | 0.0218 | 0.0014 | 0.68 | | | | | | | | |
| 12 | 120 | 120 | 39.82 | 5664.7 | 0.3 | 1534.1 | 0.758 | 3.65 | | 1.3 | 3.4 | 0.01 | 0.0086 | 0.0221 | 0.0003 | 0.39 | | | | | | | | |
| 12 | 120 | 121 | 29.84 | 5664.7 | 0.3 | 861.8 | 0.598 | 6.50 | | 0.5 | 2.0 | -0.02 | 0.0055 | 0.0232 | -0.0010 | 0.24 | | | | | | | | |
| 12 | 120 | 122 | 19.71 | 5664.7 | 0.3 | 375.8 | 0.395 | 14.92 | | 0.4 | 1.0 | -0.02 | 0.0153 | 0.0274 | -0.0029 | 0.37 | | | | | | | | |
| 12 | 120 | 123 | 10.01 | 5664.7 | 0.3 | 97.0 | 0.201 | 57.75 | | 0.3 | 0.4 | -0.01 | 0.0340 | 0.0432 | -0.0037 | 0.79 | | | | | | | | |
| 12 | 130 | 124 | 0.0 | 5634.7 | 0.0 | | | | | 3.0 | -0.3 | | | | | | | | | | | | | |
| 13 | 110 | 125 | 0.0 | 5664.7 | -1.00 | | | | | 3.1 | -0.5 | | | | | | | | | | | | | |
| 13 | 120 | 126 | 10.13 | 5664.7 | -1.00 | 99.4 | 0.203 | 56.40 | | 0.3 | 0.3 | -0.02 | 0.0332 | 0.0210 | -0.0105 | 1.23 | | | | | | | | |
| 13 | 120 | 127 | 19.95 | 5664.7 | -1.00 | 385.1 | 0.400 | 14.56 | | 1.7 | 0.9 | -0.05 | 0.0440 | 0.0234 | -0.0065 | 1.88 | | | | | | | | |
| 13 | 120 | 128 | 29.83 | 5664.7 | -1.00 | 861.0 | 0.598 | 6.51 | | 3.0 | 1.9 | -0.05 | 0.0350 | 0.0218 | -0.0031 | 1.61 | | | | | | | | |
| 13 | 120 | 129 | 19.86 | 5664.7 | -1.00 | 1235.7 | 0.798 | 3.65 | | 3.2 | 3.0 | -0.06 | 0.0205 | 0.0215 | -0.0016 | 0.95 | | | | | | | | |
| 13 | 120 | 130 | 49.74 | 5664.7 | -1.00 | 2394.3 | 0.596 | 2.34 | | 1.6 | 5.1 | -0.02 | 0.0069 | 0.0214 | -0.0004 | 0.32 | | | | | | | | |
| 13 | 120 | 131 | 59.83 | 5664.7 | -1.00 | 3460.3 | 1.198 | 1.62 | | 1.1 | 7.7 | -0.06 | 0.0033 | 0.0222 | -0.0009 | 0.15 | | | | | | | | |
| 13 | 120 | 132 | 47.81 | 5664.7 | -1.00 | 2359.8 | 0.998 | 2.34 | | 1.7 | 5.3 | -0.03 | 0.0073 | 0.0220 | -0.0007 | 0.33 | | | | | | | | |
| 13 | 120 | 133 | 39.84 | 5664.7 | -1.00 | 1535.7 | 0.798 | 3.65 | | 3.5 | 3.0 | -0.04 | 0.0146 | 0.0226 | -0.0014 | 0.87 | | | | | | | | |
| 13 | 120 | 134 | 29.86 | 5664.7 | -1.00 | 861.6 | 0.598 | 6.50 | | 2.9 | 2.1 | -0.05 | 0.005 | 0.0224 | -0.0031 | 1.37 | | | | | | | | |

THREE COMPONENT
RUN DATA CORRECTED FOR BALANCE INTERACTIONS

GALCIT Report
HSWT-1137

| RUN | CCV | CARD | VELOCITY | PRESSURE | PITCH | Q0 | RN | SIGMA | LIFT | DRAG | MOMENT | CL | CD | CM | L/D | | |
|-----|-----|------|-----------|----------|-------|--------|-------|-------|-------|------|--------|---------|--------|---------|-------|--|--|
| | | | | | | | | | | | | | | | | | |
| | | | VO,FT/SEC | PO,PSFA | DEG | | | | | | | | | | | | |
| 13 | 120 | 135 | 19.95 | 5664.7 | -1.00 | 385.1 | 0.400 | 14.56 | -1.7 | 1.1 | -0.05 | -0.0452 | 0.0288 | -0.0065 | -1.57 | | |
| 13 | 123 | 136 | 19.93 | 5664.7 | -1.00 | 95.5 | 0.199 | 58.69 | -0.3 | 0.4 | -0.02 | -0.0345 | 0.0441 | -0.0111 | -0.78 | | |
| 13 | 130 | 137 | 0.0 | 5664.7 | -1.00 | | | | 3.1 | -0.5 | 0.06 | | | | | | |
| 14 | 110 | 133 | 0.0 | 5664.7 | -2.00 | 97.0 | 0.201 | 57.75 | -1.0 | 0.3 | -0.03 | -0.1019 | 0.0277 | -0.0145 | -3.68 | | |
| 14 | 120 | 139 | 10.01 | 5664.7 | -2.00 | 384.3 | 0.399 | 14.59 | -3.9 | 0.9 | -0.07 | -0.0117 | 0.0235 | -0.0085 | -4.33 | | |
| 14 | 120 | 140 | 19.93 | 5664.7 | -2.00 | 863.3 | 0.598 | 6.49 | -6.4 | 1.9 | -0.08 | -0.0142 | 0.0222 | -0.0044 | -3.34 | | |
| 14 | 123 | 141 | 29.87 | 5664.7 | -2.00 | 1532.6 | 0.797 | 3.66 | -7.3 | 3.3 | -0.09 | -0.0173 | 0.0214 | -0.0028 | -2.22 | | |
| 14 | 123 | 142 | 39.80 | 5664.7 | -2.00 | 2399.8 | 0.998 | 2.34 | -6.7 | 5.1 | -0.10 | -0.0281 | 0.0211 | -0.0020 | -1.33 | | |
| 14 | 120 | 143 | 49.80 | 5664.7 | -2.00 | 3464.2 | 1.199 | 1.62 | -7.2 | 7.4 | -0.16 | -0.0207 | 0.0214 | -0.0026 | -0.97 | | |
| 14 | 123 | 144 | 59.83 | 5664.7 | -2.00 | 2400.6 | 0.598 | 2.33 | -6.9 | 5.1 | -0.11 | -0.0286 | 0.0214 | -0.0023 | -1.34 | | |
| 14 | 120 | 145 | 49.81 | 5664.7 | -2.00 | 1516.4 | 0.798 | 3.65 | -7.1 | 3.4 | -0.10 | -0.0163 | 0.0224 | -0.0032 | -2.06 | | |
| 14 | 120 | 145 | 39.85 | 5664.7 | -2.00 | 857.9 | 0.598 | 6.53 | -6.1 | 2.3 | -0.08 | -0.0703 | 0.0237 | -0.0048 | -2.59 | | |
| 14 | 120 | 147 | 29.78 | 5664.7 | -2.00 | 382.0 | 0.398 | 14.67 | -3.7 | 1.0 | -0.07 | -0.0974 | 0.0271 | -0.0085 | -3.59 | | |
| 14 | 120 | 148 | 19.87 | 5664.7 | -2.00 | 57.8 | 0.201 | 57.30 | -0.9 | 0.4 | -0.03 | -0.0963 | 0.0373 | -0.0144 | -2.58 | | |
| 14 | 123 | 149 | 10.05 | 5664.7 | -2.00 | | | | 3.1 | -0.4 | 0.06 | | | | | | |
| 14 | 130 | 153 | 0.0 | 5664.7 | -2.00 | | | | 3.1 | -0.5 | 0.06 | | | | | | |
| 15 | 110 | 151 | 0.0 | 5664.7 | -3.00 | 98.6 | 0.202 | 56.84 | -1.8 | 0.3 | -0.03 | -0.1815 | 0.0274 | -0.0146 | -6.63 | | |
| 15 | 120 | 152 | 10.09 | 5664.7 | -3.00 | 382.8 | 0.398 | 14.64 | -6.0 | 0.9 | -0.07 | -0.1575 | 0.0242 | -0.0087 | -6.52 | | |
| 15 | 120 | 153 | 19.89 | 5664.7 | -3.00 | 861.0 | 0.598 | 6.51 | -9.7 | 1.9 | -0.09 | -0.1127 | 0.0225 | -0.0053 | -5.00 | | |
| 15 | 120 | 154 | 29.83 | 5664.7 | -3.00 | 1541.1 | 0.799 | 3.64 | -11.5 | 3.4 | -0.12 | -0.0749 | 0.0220 | -0.0038 | -3.40 | | |
| 15 | 120 | 155 | 39.91 | 5664.7 | -3.00 | 2600.6 | 0.999 | 2.33 | -12.0 | 5.2 | -0.17 | -0.0498 | 0.0215 | -0.0035 | -2.32 | | |
| 15 | 120 | 156 | 49.81 | 5664.7 | -3.00 | 3461.9 | 1.198 | 1.62 | -13.7 | 7.8 | -0.31 | -0.0396 | 0.0225 | -0.0044 | -1.76 | | |
| 15 | 120 | 157 | 59.81 | 5664.7 | -3.00 | 2397.4 | 0.597 | 2.34 | -12.2 | 5.3 | -0.19 | -0.0509 | 0.0222 | -0.0040 | -2.29 | | |
| 15 | 120 | 158 | 49.78 | 5664.7 | -3.00 | 1535.3 | 0.797 | 3.65 | -11.3 | 3.4 | -0.14 | -0.0737 | 0.0224 | -0.0044 | -3.29 | | |
| 15 | 120 | 159 | 39.81 | 5664.7 | -3.00 | 803.3 | 0.598 | 6.49 | -9.5 | 2.1 | -0.10 | -0.1086 | 0.0248 | -0.0161 | -4.61 | | |
| 15 | 120 | 160 | 29.87 | 5664.7 | -3.00 | 387.4 | 0.401 | 14.47 | -6.1 | 1.1 | -0.07 | -0.1568 | 0.0278 | -0.0095 | -5.64 | | |
| 15 | 120 | 161 | 20.01 | 5664.7 | -3.00 | 99.4 | 0.203 | 56.43 | -1.9 | 0.4 | -0.03 | -0.1896 | 0.0445 | -0.0146 | -4.26 | | |
| 15 | 130 | 163 | 0.0 | 5664.7 | -3.00 | | | | 3.1 | -0.3 | 0.06 | | | | | | |
| 16 | 110 | 164 | 0.0 | 5664.7 | -4.00 | | | | 3.1 | -0.5 | 0.07 | | | | | | |
| 16 | 120 | 165 | 10.13 | 5664.7 | -4.00 | 99.4 | 0.203 | 56.40 | -2.5 | 0.3 | -0.04 | -0.2512 | 0.0292 | -0.0101 | -8.61 | | |
| 16 | 120 | 166 | 19.67 | 5664.7 | -4.00 | 382.0 | 0.348 | 14.67 | -8.1 | 0.9 | -0.09 | -0.2121 | 0.0248 | -0.0116 | -8.56 | | |
| 16 | 120 | 167 | 29.63 | 5664.7 | -4.00 | 861.0 | 0.598 | 6.51 | -13.0 | 2.0 | -0.12 | -0.1110 | 0.0228 | -0.0070 | -6.62 | | |
| 16 | 120 | 168 | 39.91 | 5664.7 | -4.00 | 1540.3 | 0.799 | 3.64 | -15.6 | 3.5 | -0.17 | -0.1012 | 0.0227 | -0.0054 | -4.46 | | |
| 16 | 120 | 169 | 45.79 | 5664.7 | -4.00 | 2379.0 | 0.597 | 2.34 | -16.9 | 5.3 | -0.25 | -0.1073 | 0.0223 | -0.0052 | -3.15 | | |
| 16 | 120 | 170 | 59.63 | 5664.7 | -4.00 | 3460.1 | 1.198 | 1.62 | -19.3 | 7.8 | -0.42 | -0.0557 | 0.0224 | -0.0060 | -2.48 | | |
| 15 | 120 | 171 | 49.80 | 5664.7 | -4.00 | 2399.8 | 0.958 | 2.34 | -17.0 | 5.5 | -0.27 | -0.0738 | 0.0228 | -0.0057 | -3.11 | | |
| 16 | 120 | 172 | 39.65 | 5664.7 | -4.00 | 1536.4 | 0.793 | 3.65 | -15.4 | 3.6 | -0.19 | -0.1002 | 0.0231 | -0.0061 | -4.33 | | |
| 16 | 120 | 173 | 29.84 | 5664.7 | -4.00 | 861.8 | 0.598 | 6.53 | -12.5 | 2.1 | -0.13 | -0.1448 | 0.0241 | -0.0078 | -6.00 | | |

GALCIT Report
HSWT-1137

THREE COMPONENT
RUN DATA CORRECTED FOR BALANCE INTERACTIONS

CONSTANTS: TEMP= 74.00000 DEG F
PV= 59.84639 PSF
WW= 62.19731 LB/CUFT
LC= 0.20303 FT

CONSTANTS: TEMP= 74.59999 DEG F
PV= 61.07324 PSF
WW= 62.19345 LB/CUFT
LC= 0.20303 FT

CONSTANTS: TEMP= 74.00000 DEG F
PV= 59.84639 PSF
WW= 62.19731 LB/CUFT
LC= 0.20303 FT

| RUN CCN CARD | VELOCITY | PRESSURE | PITCH | 00 | RN | SIGMA | LIFT | DRAG | MOMENT | CL | CD | CM | L/D |
|--------------|----------|----------|-------|--------|--------|-------|--------|--------|----------|---------|--------|---------|-------|
| W0, FT/SEC | PSF | PSF | DEG | PSF | 10 E-6 | 1 | L, LBS | D, LBS | H, FT-LB | | | | |
| 15 120 174 | 19.99 | 5664.7 | -4.00 | 386.6 | 0.400 | 14.50 | -7.9 | 1.1 | -0.10 | -0.2046 | 0.0284 | -0.0123 | -7.23 |
| 16 120 175 | 10.01 | 5664.7 | -4.30 | 97.0 | 0.201 | 51.75 | -2.5 | 0.4 | -0.04 | -0.2572 | 0.0437 | -0.0221 | -5.69 |
| 16 130 176 | 0.0 | 5664.7 | -4.00 | | | | 3.1 | -0.3 | 0.06 | | | | |
| 17 110 177 | 0.0 | 5664.7 | -4.00 | | | | 3.0 | -0.4 | 0.07 | | | | |
| 17 120 178 | 45.81 | 5664.7 | -6.00 | 2400.6 | 0.998 | 2.33 | -17.0 | 5.3 | -0.26 | -0.0706 | 0.0219 | -0.0054 | -3.23 |
| 17 120 179 | 49.84 | 5664.7 | -0.60 | 2403.7 | 0.998 | 2.33 | 0.2 | 4.9 | -0.03 | 0.0008 | 0.0206 | -0.0006 | 0.04 |
| 17 130 180 | 0.0 | 5664.7 | -0.60 | | | | 3.0 | -0.4 | 0.06 | | | | |

| RUN CCN CARD | VELOCITY | PRESSURE | PITCH | 00 | RN | SIGMA | LIFT | DRAG | MOMENT | CL | CD | CM | L/D | |
|--------------|----------|----------|-------|--------|--------|-------|--------|--------|----------|---------|---------|---------|---------|-------|
| W0, FT/SEC | PSF | PSF | DEG | PSF | 10 E-6 | 1 | L, LBS | D, LBS | H, FT-LB | | | | | |
| 18 110 181 | 0.0 | 5616.5 | -4.00 | | | | 0.5 | -0.6 | 0.35 | -0.04 | -0.2486 | 0.0275 | -0.0182 | -9.04 |
| 13 120 182 | 10.09 | 5636.5 | -4.00 | 98.6 | 0.204 | 56.55 | -2.4 | 0.3 | -0.04 | -0.2112 | 0.0247 | -0.0115 | -8.56 | |
| 19 120 183 | 19.91 | 5636.5 | -4.00 | 383.5 | 0.402 | 14.54 | -8.1 | 0.9 | -0.09 | -0.1504 | 0.0228 | -0.0078 | -6.59 | |
| 13 120 184 | 29.83 | 5616.5 | -4.00 | 861.0 | 0.602 | 6.48 | -13.0 | 2.0 | -0.13 | -0.0220 | 0.0220 | -0.0058 | -4.62 | |
| 18 120 185 | 39.51 | 5636.5 | -4.30 | 1535.6 | 0.807 | 3.63 | -15.6 | -3.4 | -0.18 | -0.018 | 0.0213 | -0.0154 | -3.28 | |
| 18 120 186 | 49.78 | 5636.5 | -4.00 | 2397.3 | 1.005 | 2.33 | -11.1 | 5.2 | -0.26 | -0.0717 | 0.0224 | -0.0060 | -2.51 | |
| 18 120 187 | 59.81 | 5636.5 | -4.00 | 3460.9 | 1.207 | 1.61 | -19.4 | 7.7 | -0.42 | -0.0561 | 0.0218 | -0.0057 | -3.18 | |
| 18 120 188 | 49.77 | 5616.5 | -4.00 | 2396.5 | 1.005 | 2.33 | -17.2 | 5.4 | -0.27 | -0.0717 | 0.0226 | -0.0057 | -3.18 | |
| 18 120 189 | 19.93 | 5636.5 | -4.00 | 384.3 | 0.402 | 14.51 | -7.8 | 1.1 | -0.10 | -0.2034 | 0.0276 | -0.0124 | -7.37 | |
| 18 130 190 | 0.0 | 5636.5 | -4.00 | | | | 0.3 | -0.5 | 0.06 | | | | | |
| 19 110 191 | 0.0 | 5636.5 | 1.00 | | | | 0.4 | -0.6 | 0.36 | | | | | |
| 19 120 192 | 10.09 | 5636.5 | 1.00 | 98.6 | 0.204 | 56.55 | 1.2 | 0.3 | 0.00 | 0.1194 | 0.0228 | 0.00301 | 3.64 | |
| 19 120 193 | 19.95 | 5636.5 | 1.00 | 385.1 | 0.403 | 14.48 | 3.1 | 1.3 | -0.01 | 0.0807 | 0.0326 | -0.0009 | 2.47 | |
| 19 120 194 | 29.82 | 5636.5 | 1.00 | 860.2 | 0.602 | 6.48 | 4.3 | 3.1 | -0.00 | 0.098 | 0.0359 | -0.0002 | 1.39 | |
| 19 120 195 | 39.53 | 5636.5 | 1.00 | 1534.8 | 1.00 | 3.63 | 5.7 | 5.8 | -0.03 | 0.0374 | 0.0378 | -0.0011 | -0.99 | |
| 19 130 196 | 0.0 | 5636.5 | 1.00 | | | | 0.4 | -0.6 | 0.06 | | | | | |

TABLE III
Measured Deflections on Rubber Model

| Data Pt. | a, Deg. | Vel., * ft/sec. | Y Elevation, in. | | Data Pt. | a, Deg. | Vel., * ft/sec. | Y Elevation, in. | |
|----------|---------|-----------------|------------------|-------|----------|---------|-----------------|------------------|-------|
| | | | Nose | T. E. | | | | Nose | T. E. |
| 98 | +1 | 0 | 1.577 | Nose | 125 | -1 | 0 | 1.595 | -- |
| 99 | " | 10 | 1.573 | " | 126 | " | 10 | 1.600 | 1.588 |
| 100 | " | 20 | 1.557 | " | 127 | " | 20 | 1.609 | 1.587 |
| 101 | " | 30 | 1.549 | " | 128 | " | 30 | 1.616 | 1.595 |
| 102 | " | 40 | 1.545 | " | 129 | " | 40 | 1.619 | 1.600 |
| 103 | " | 50 | 1.533 | " | 130 | " | 50 | 1.622 | 1.591 |
| 104 | " | 60 | 1.522 | " | 131 | " | 60 | 1.623 | 1.591 |
| " | " | " | 1.522 | T. E. | 132 | " | 50 | 1.625 | 1.591 |
| 105 | " | 50 | 1.530 | " | 133 | " | 40 | 1.621 | 1.592 |
| 106 | " | 40 | 1.561 | " | 134 | " | 30 | 1.619 | 1.594 |
| 107 | " | 30 | 1.580 | " | 135 | " | 20 | 1.609 | 1.589 |
| 108 | " | 20 | 1.600 | " | 136 | " | 10 | 1.605 | 1.575 |
| 109 | " | 10 | 1.622 | " | 137 | " | 0 | 1.603 | 1.584 |
| 110 | " | 0 | 1.641 | " | 138 | -2 | 0 | 1.610 | 1.548 |
| 112 | 0 | 0 | 1.611 | " | 139 | " | 10 | 1.615 | 1.549 |
| 113 | " | 10 | 1.603 | " | 140 | " | 20 | 1.634 | 1.580 |
| 114 | " | 20 | 1.595 | " | 141 | " | 30 | 1.646 | 1.599 |
| 115 | " | 30 | 1.598 | " | 142 | " | 40 | 1.654 | 1.614 |
| 116 | " | 40 | 1.587 | " | 143 | " | 50 | 1.666 | 1.615 |
| 117 | " | 50 | 1.561 | " | 144 | " | 60 | 1.670 | 1.631 |
| 118 | " | 60 | 1.559 | " | 145 | " | 50 | 1.666 | 1.610 |
| " | " | " | 1.569 | Nose | 146 | " | 40 | 1.655 | 1.616 |
| 119 | " | 50 | 1.577 | " | 147 | " | 30 | 1.651 | 1.605 |
| 120 | " | 40 | 1.581 | " | 148 | " | 20 | 1.636 | 1.582 |
| 121 | " | 30 | 1.586 | " | 149 | " | 10 | 1.618 | 1.554 |
| 122 | " | 20 | 1.586 | " | 150 | " | 0 | 1.608 | 1.550 |
| 123 | " | 10 | 1.586 | " | | | | | |
| 124 | " | 0 | 1.589 | " | | | | | |

* Nominal Velocity

TABLE III (Cont'd.)

Measured Deflections on Rubber Model

| Data Pt. | a, Deg. | Vel., ft/sec. | Y Elevation, in. | |
|----------|---------|------------------|------------------|-------|
| | | | Nose | T. E. |
| 151 | -3 | 0 | 1.620 | 1.518 |
| 152 | " | 10 | 1.632 | 1.530 |
| 153 | " | 20 | 1.658 | 1.573 |
| 154 | " | 30 | 1.679 | 1.613 |
| 155 | " | 40 | 1.694 | 1.625 |
| 156 | " | 50 | 1.710 | 1.644 |
| 157 | " | 60 | 1.721 | 1.656 |
| 158 | " | 50 | 1.710 | 1.646 |
| 159 | " | 40 | 1.698 | 1.633 |
| 160 | " | 30 | 1.682 | 1.615 |
| 161 | " | 20 | 1.662 | 1.580 |
| 162 | " | 10 | 1.637 | 1.535 |
| 163 | " | 0 | 1.623 | 1.520 |

*Nominal Velocity

NSRDC FAIRED TOWLINE TESTS
IN THE HIGH SPEED WATER TUNNEL

Discussion

This report presents the results of water tunnel tests conducted on two full-scale models of a segment of the NSRDC towline (NACA 0020 airfoil profile). The primary function was to measure lift, drag and pitching moment and trailing edge deflections as a function of pitch angle on a partially elastic model. Tests were also conducted on an aluminum version model of the towline segment to serve as a data base for comparison.

These tests were conducted in the two-dimensional working section of the High Speed Water Tunnel (HSWT) in the GALCIT Hydrodynamics Laboratory*. This tunnel, which uses a closed circuit, has a choice of either a two-dimensional (6" x 30") or axi-symmetric (14" D.) working section (see Fig. 1).

Of the two models (NACA 0020 airfoil profile) used for these tests, one was fabricated from silicone rubber bonded to an epoxy bound glass fiber strength member and covered with a silicone rubber impregnated fabric (see Fig. 3, also lower model in Fig. 4). The other model of the towline segment was fabricated from aluminum. (See Fig. 4, mounted model.) The models had a span of 6 inches with a chord length of 2.4 inches.

Models were supported on the three component strain gage balance which is mounted on the side wall of the working section (see Fig. 2).

* For a more complete description of this laboratory see: Ward, T. M. "The Hydrodynamics Laboratory at the California Institute of Technology 1976", J. Fluids Engineering, ASME, December 1976.

The opposite sidewall consists of a 1.75 inch thick aluminum plate with a 7.5 inch diameter circular plexiglas viewing window. Tip clearance between the model and the viewing window was set at 0.009 inches.

Data recorded during these tests include three component force and moment data which are recorded simultaneously for each data point on IBM punched cards using an automatic data acquisition system. These data are reduced to the final coefficient forms defined in Table I. Deflections of the elastic model were also measured by means of a two directional cathetometer mounted at the viewing port. Leading and trailing edge deflection data, measured at the free end of the model, are presented in Table III commencing with data point number 98.

Data Reduction and Accuracy

Signals from the force balance, manometer readings, model settings, physical constants, and other data were recorded on punched cards and reduced using digital computer processing techniques. These data are presented in Table II. Data for run numbers 1 through 4 correspond to the aluminum model and those from runs 5 through 19 correspond to the silicone rubber model.

Manometer indications of velocity in the working section exhibit a natural oscillation which has a maximum amplitude change varying from approximately $\pm 5\%$ at 10 ft/sec to $\pm 1\%$ at 60 ft/sec. The oscillation is slow and exhibits periods when no fluctuation is detectable. Data are recorded during these periods of zero fluctuations and it is believed that the velocity data presented here are accurate to within $\pm 0.5\%$.

Working section pressure indicators exhibit similar oscillations, however, the maximum excursions are not as large and the data presented here are also believed to be accurate to within $\pm 0.5\%$.

Angle of attack settings are accurate to within ± 0.1 degree. No allowances or corrections have been made to adjust for model deflections due to applied loads, mounting plate tare or tunnel boundary effects.

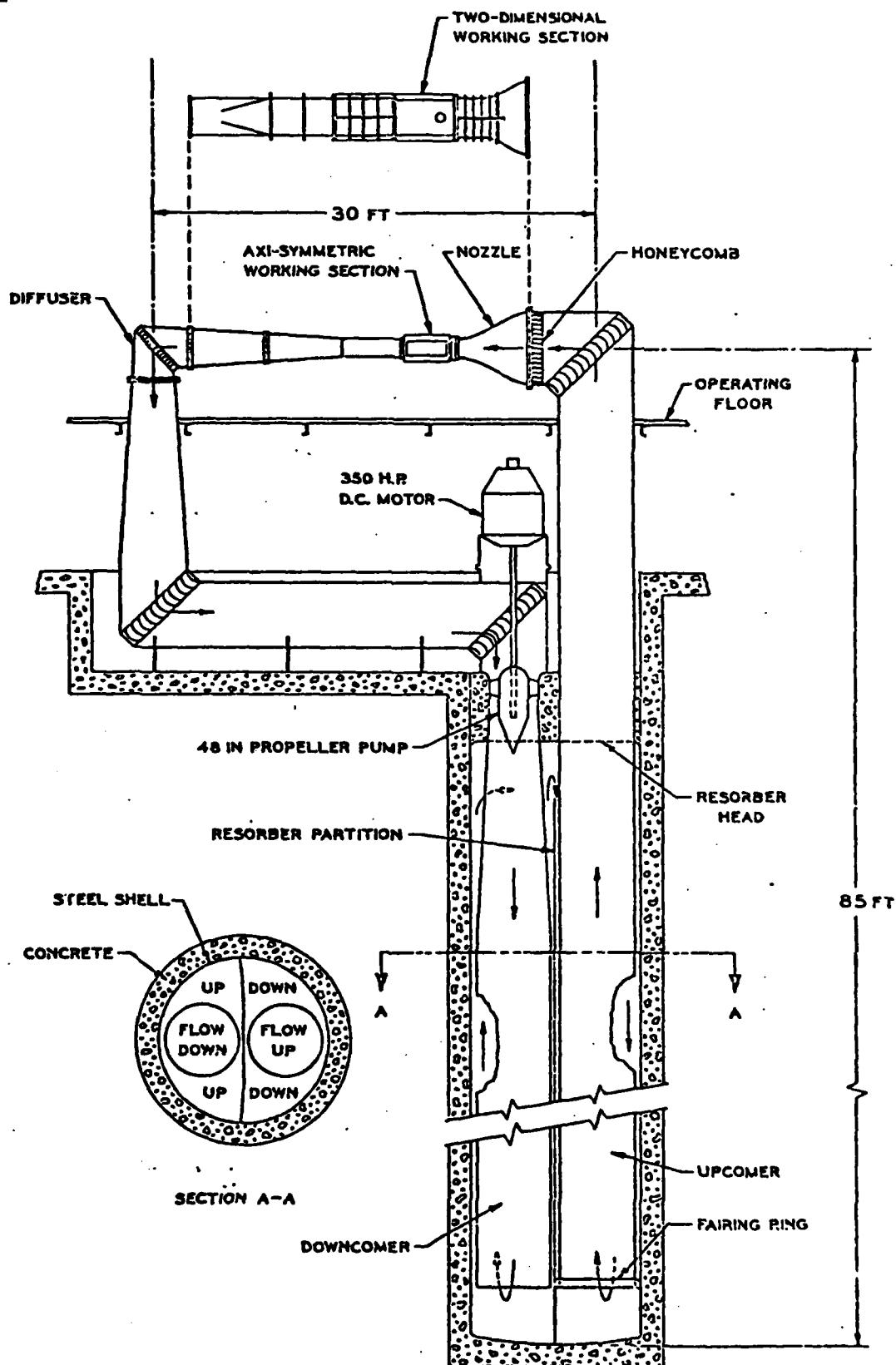
The output of all balance gages, including hysteresis, nonlinearity and repeatability are linear to within $\pm 0.25\%$ of full range. The data system used to process and record the output is accurate to within $\pm 0.1\%$ of the indicated value. As a result of the above, the force and moment data presented are believed to be accurate to within the following limits:

Lift force; ± 0.5 lbs.

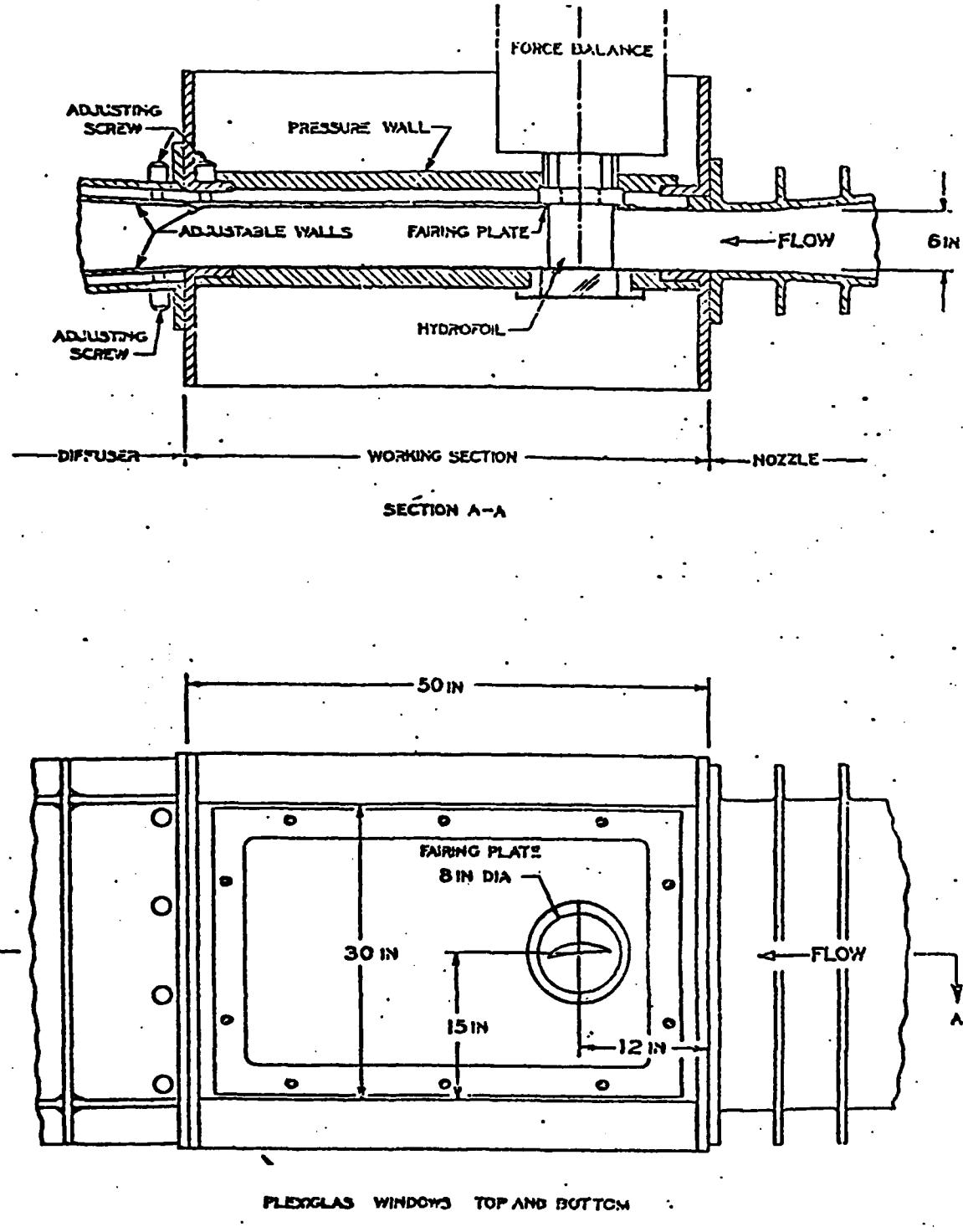
Drag force, ± 0.2 lbs.

Pitching moment; ± 0.75 lb.-in.

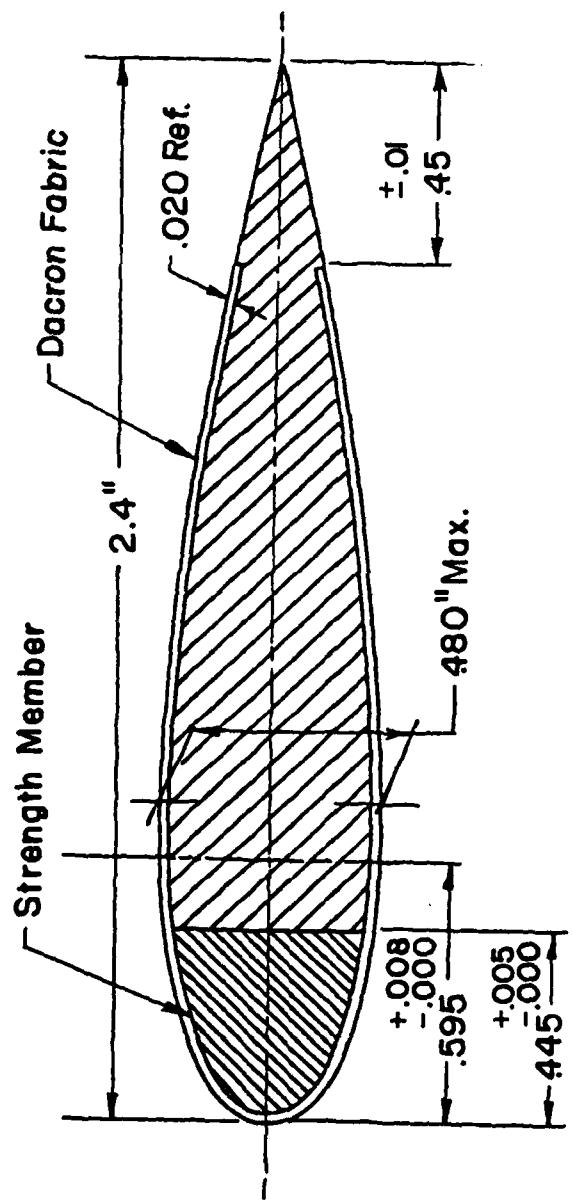
This work was performed for the U.S. Navy under Contract No. N00014-78-C-0790.



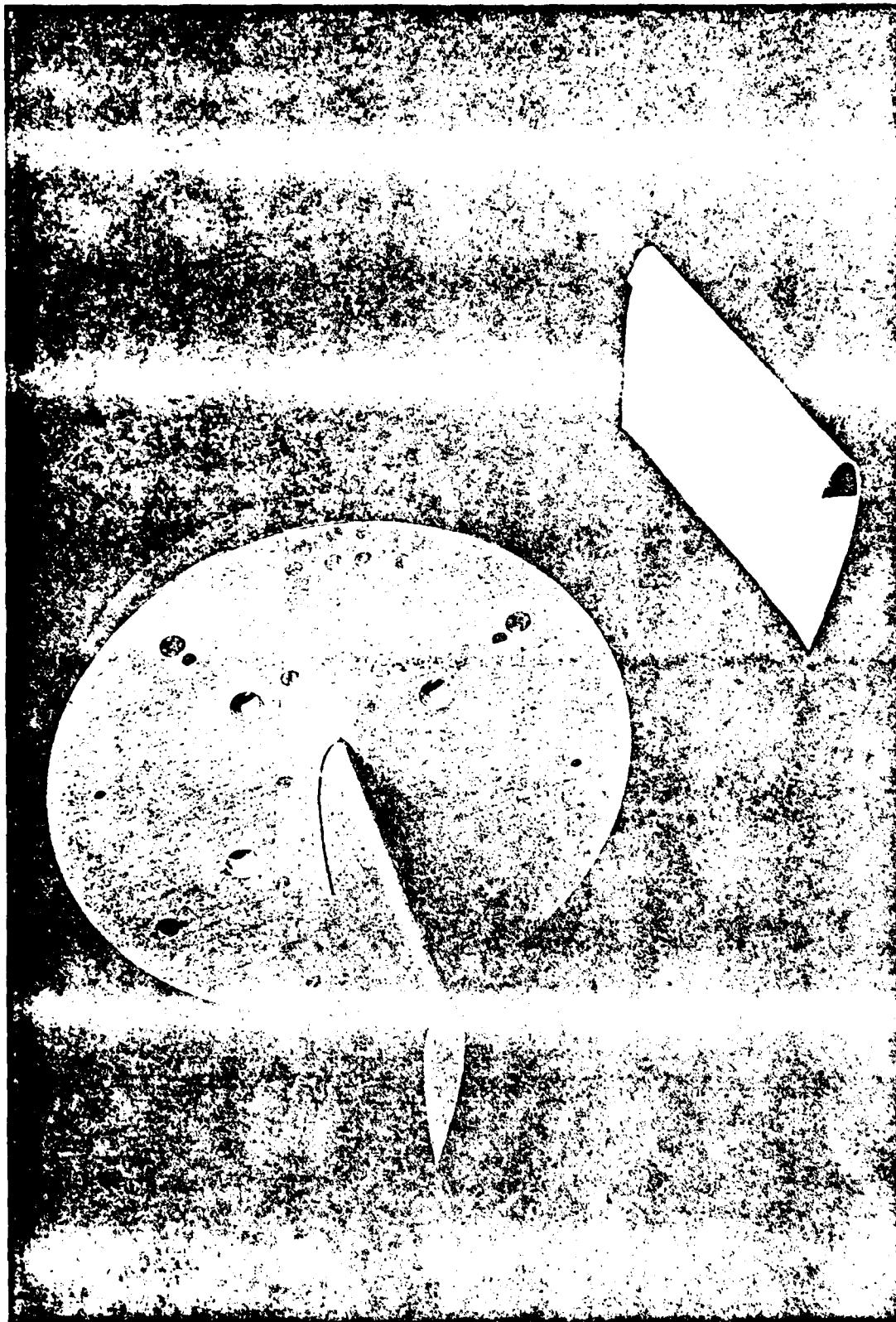
High Speed Water Tunnel Circuit Schematic



Two-Dimensional Working Section Schematic



Cross-Section of Flexible Model



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Models of Segment of
NSRDG Fair'd Towline